

Evidence for CO₂-rich fluids in rocks from the "type" charnockite area near Pallavaram, Tamil Nadu

61

E. Hansen¹, W. Hunt¹, S. C. Jacob², K. Morden¹, R. Reddi², P. Tacy¹

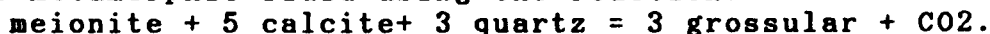
Authorship in alphabetical order

- 1) Geology Department, Hope College. Holland, Michigan
- 2) Department of Applied Geology, University of Madras, Madras

Charnockitic rocks were first described by Sir Thomas Holland (1900) from the hills around the village of Pallavaram south of Madras. In this area a series of acid to intermediate magmas intruded an interbedded sequence of predominately pelitic and mafic rocks which were latter metamorphosed to high grade (Subramaniam, 1959). According to Weaver (1980) chemical trends in the charnockites indicate a period of metasomatism and partial melting immediately preceeding the granulite-facies metamorphism which he suggests was due to an influx of CO₂-rich fluids. On the other hand, Bhattacharya and Sen (1986) concluded that no pervasive fluid was present during the high-grade metamorphism which involved internal buffering of fluids and dehydration melting. They based their conclusions largely on calculations of metamorphic water activities which are different for different rock types and show systematic variations with mineral chemistry. We have examined rocks from a quarry southeast of Pallavaram for evidence indicating the concentration of carbon-dioxide in the metamorphic-fluid phase.

Charnockitic rocks are the major rock type exposed in the quarry. These rocks are cut by coarse-grained dykes and veins also made up of dark charnockite. Mafic granulites occur as enclaves. One especially large mafic enclave contains light colored veins made up of calcite and scapolite with smaller amounts of diopside and quartz. Garnets are concentrated at the margins of these veins. The dark host rock has a granulitic texture and is made up of hornblende, diopside, plagioclase and quartz with sporadic garnet.

Results of EDS electron-microprobe analyses on minerals from the mafic host and calcite-bearing veins are given in Table 1. W.D.S. analyses of the scapolite indicate only small amounts (less than 0.1 wt%) of sulfur or chlorine. The mineral assemblage at the edges of the vein allow us to estimate the CO₂ concentration in the metamorphic fluid using the reaction:



Calculations using the thermodynamic data of Holland and Powell (1985) indicate a nearly pure CO₂ fluid under the metamorphic temperatures (750-800°C) and pressures (6.5 - 7.5 kbars) obtained for the area by Bhattacharya and Sen (1986).

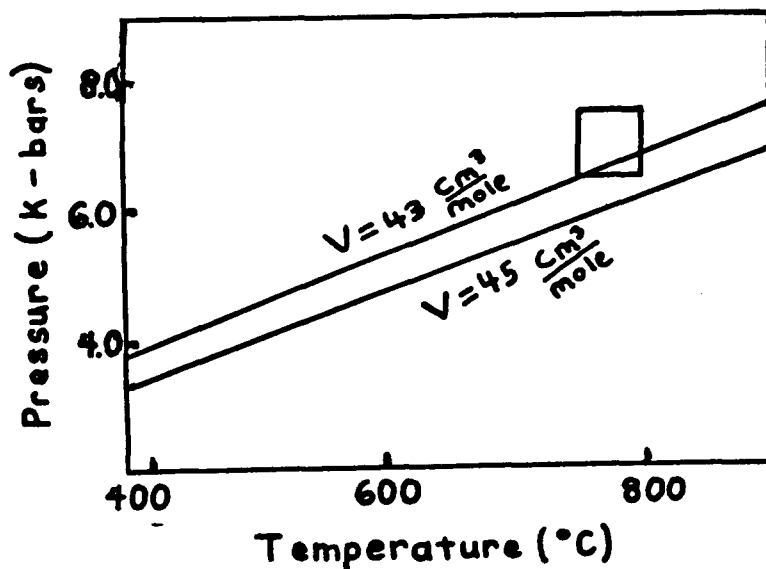
Carbonic fluid inclusions are abundant in a sample of one of the coarse-grained charnockitic veins collected near the mafic enclave. The vein is roughly granitic in composition containing the assemblage alkali-feldspar, plagioclase, quartz, orthopyroxene and opaques. The fluid inclusions occur in planar arrays and are hence secondary or pseudosecondary. Melting temperatures obtained on these inclusions are all within 1°C of the melting temperatures of a pure CO₂ standard. Thus the fluid is nearly pure CO₂ although small (up to about 20%) amounts of water may be present

Table 1 - Mineral Compositions

	Garnet		Diopside		Scapolite	Plag
	Host Rock	Vein	Host Rock	Vein	Vein	Host Rock
SiO ₂	37.6	37.7	50.5	48.3	42.9	49.7
Al ₂ O ₃	21.5	21.0	2.3	2.5	30.2	33.1
FeO	27.4	25.9	16.8	24.1		
MnO	1.3	0.8				
MgO	2.3	1.5	8.9	4.5		
CaO	10.8	13.3	21.9	21.7	20.4	15.1
Na ₂ O					1.6	2.1
Total	100.9	100.2	100.4	101.1	95.1	100.0
Si	2.94	2.99	1.94	1.92	6.59	2.26
Al	1.99	1.96	0.10	0.12	5.47	1.77
Fe	1.79	1.72	0.54	0.80		
Mn	0.09	0.06				
Mg	0.26	0.18	0.52	0.27		
Ca	0.91	1.13	0.90	0.93	3.37	0.74
Na					0.47	0.19

as a thin, undetected, immiscible layer against the walls of the inclusions. Homogenization temperatures cluster between -9°C and -18°C and hence have specific volume between 43 and $45\text{ cm}^3/\text{mole}$. Isochores for those two volumes, calculated with the equations of Touret and Bottinga (1979) are given in Figure 1. The box in the figure outlines the metamorphic conditions for the area deduced by Bhattacharya and Sen (1986). Isochores for the denser fluid inclusions pass through this box. If small amounts of water are present as an immiscible fluid, then the isochores in Figure 1 should be moved to slightly higher pressures and this would increase the overlap with the metamorphic conditions.

Figure 1



The fluid inclusions indicate that a dense CO₂-rich fluid was present at some point in the history of the charnockite. It is difficult to see how the mineral assemblages in the charnockite or its igneous precursor could have generated CO₂, hence it probably flowed in from the outside. The densities of these fluids are approximately consistent with entrapment at peak metamorphic conditions as would be predicted by the CO₂-influx model of Weaver (1980). However, high densities are no guarantee that the fluid actually represents the peak metamorphic fluid nor is the presence of CO₂-rich fluids necessarily incompatible with other models of granulite-facies metamorphism (Crawford and Hollister, 1986).

An influx of CO₂ should lead to "carbonated" mineral assemblages in rocks of the appropriate bulk compositions. This may be the case with the carbonate-bearing veins in the mafic enclave, although it is by no means certain that the veins are metasomatic. The sporadic occurrence of garnet in the host rock without scapolite or calcite suggests lower CO₂ fugacities than in the veins and hence indicates some heterogeneity in the metamorphic fluid phase. According to Subramaniam (personal communication, 1983) wollastonite-bearing veins had also been found in the mafic enclaves in this quarry. Wollastonite is not stable in the presence of a CO₂-rich fluid during granulite facies conditions (Valley, 1985) and hence its presence may indicate large heterogeneities in the metamorphic fluid. Unfortunately, we were unable to locate any of the wollastonite-bearing veins and have little indication of how they fit into the metamorphic history of the area.

We have evidence that a dense CO₂-rich fluid was once present in the rocks exposed in the type charnockite area around Pallavaram. This gives some support to the idea proposed by Weaver (1980) that the granulite-facies metamorphism in this area was due to the influx of a CO₂-rich fluid. However, important questions still remain about the timing of CO₂ influx, the pervasiveness of the CO₂-rich fluid, and its source. Thus, for example, our results are also consistent with a model in which the bulk of the granulite-facies metamorphism occurred through dehydration melting accompanied or followed by some localized migration of CO₂-rich fluids. This is a model very similar to the one proposed by Bhattacharya and Sen (1986). More information will be needed, especially about the thermal history of the area and stable isotope compositions, before the role of the CO₂-rich fluid can be resolved.

References

- Bhattacharya and Sen (1986) *Journ. Petrol.* 17, 1119-1141.
Crawford, M.L. and Hollister, L.S. (1986) *Advances in Physical Geochemistry.* 5, 1-35.
Holland, T.H. (1900) *Geol. Survey India Mem.* 28, 119-249.
Holland, T.J.B., and Powell, R., (1985) *J. Metamorphic Geol.* 3, 343-320.
Subramaniam, A.P. (1959) *Amer. Journ. Sci.* 257, 321-353.
Touret, J. and Bottinga, Y. (1979) *Bull. Mineral.* 102, 577-583
Valley, J.W. (1985) *The Deep Proterozoic Crust in the North Atlantic Provinces*, 217-236.
Weaver, B.L. (1980) *Contrib. Mineral Petrol.* 71, 271-279.